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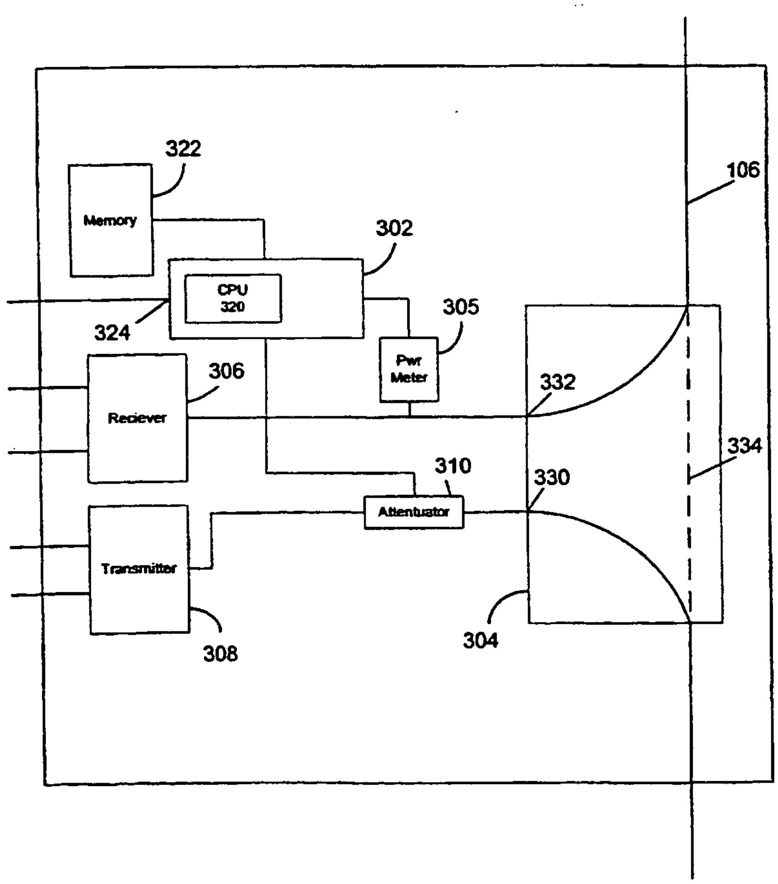

(57) Abstract: A method and apparatus for transmitting a signal over a network. The network includes a central node (102) and one or more branch nodes (104) connected by a transmission medium (110). The transmission medium (110) includes one or more signal channels. Each branch node (104) includes an add/drop filter (304) operable to receive signals on the same channels for transmission to one or more other nodes (104) in the network. The method includes receiving a signal on at least one signal channel at a first node, determining a receive power level of the signal, generating a transmit signal for transmission to a second node, adjusting a power level of the transmit signal to approximate the receive power level and transmitting the adjusted transmit signal on the at least one signal channel to the second node.

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INTELLIGENT POWER CONTROLLER

BACKGROUND OF THE INVENTION

The present invention relates generally to network communications systems and more specifically to a system and method for maximizing loss budgets in a ring-based wavelength division multiplexing system.

SUMMARY OF THE INVENTION

In a simple form, a communications network includes a plurality of stations coupled by a transmission media (e.g., cable wire or optical fiber) over which the stations communicate. Examples of communications networks include telecommunication systems, cable television systems and local area or other computer networks. Information systems engineers that design and support conventional communications networks face numerous challenges as network traffic increases, especially with the increased use of the worldwide web. The communication infrastructure (including the transmission media) in many conventional communications networks is reaching or has reached capacity as a result. While it may be possible to install new or additional transmission media to accommodate the increasing load, this is a costly solution. It would therefore be beneficial to be able to increase the volume of information that can be handled without exponentially increasing the cost.

The communications infrastructure for a communications network includes a physical configuration that is referred to as a topology. A ring topology, for example, connects network nodes in a loop or ring. Information is transferred from a source node to a next node, and so on, around the ring to reach a destination node. A ring topology has the advantage of minimizing the amount of transmission media that must be used to connect the nodes in the network. However, the amount of information that can be transmitted (i.e., the bandwidth) is limited in a ring topology.

In contrast to a ring topology, a star topology connects branch nodes to a central node in a spoke-like fashion. Information is transmitted from one branch node to another via the central node. A star topology has the advantage of having a central node that can be used to link to another communications system. Further, a branch node that is

connected to the central node can use the full bandwidth of the connection between a respective node and the central node. That is, the branch node does not need to share any bandwidth between itself and other nodes when communicating with the central node. The star topology advantageously can provide the full bandwidth between a branch node and a central node. However, the communications infrastructure required to support a star topology is significantly greater than that for a ring topology. Recognizing the need to overcome these issues, a number of solutions have been proposed.

As described above, in a ring topology a single communication channel is shared between the nodes connected on the ring. In an effort to increase the bandwidth of a conventional ring configuration, two mechanisms have been developed for proportioning the networks bandwidth. These two mechanisms are time division multiplexing (TDM) and wavelength division multiplexing (WDM).

In a TDM system, the transmission bandwidth of the ring's single communication channel is broken up into intervals or slots of time. In a given time interval a node is given that single channel's full bandwidth. Where there are n nodes, there are $\frac{1}{n}$ time slots. Thus, each of the n nodes may transmit information $\frac{1}{nth}$ of the time. Each node is enabled to send up to the full bandwidth of data in its respective time slot. The length of time associated with a time slot may necessitate information being split up into multiple transmissions or packets that are combined to form a complete transmission at a destination node. A disadvantage of a TDM system is that the nodes still may share only a fraction of the total available bandwidth of the communications network. The more nodes present in the communications network, the smaller the amount of time allotted to each node.

Instead of dividing a network's bandwidth into time slots, a WDM system divides a network's bandwidth into signal channels, where each signal channel is assigned a particular channel wavelength. This allows multiple signals (each a different wavelength) to be carried on the same transmission media. For example, multiple optical signal channels can be used by a fiber optic cable to transmit multiple signals on the same cable. Each signal channel operates at the network's full bandwidth. Thus, a node can use the full bandwidth of the network by sending information on one of these signal channels.

The signals are multiplexed in a WDM system at a transmitting end and transmitted to a receiving end where they are demultiplexed into individual signals. In

conventional systems, the transmitting and receiving ends must be tuned to the same wavelengths to be able to communicate. That is, the transmitting and receiving ends use a device such as an add/drop multiplexor to transmit/receive a fixed signal channel. In the case of fiber optic cable, an add/drop multiplexor is used at the transmitting and receiving ends to generate a fixed wavelength (e.g., using lasers) signal and to receive a fixed wavelength signal. Conventional systems can have as many as 16 to 40 signal channels.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic block diagram of a virtual star network

Figure 2 is a schematic block diagram showing the physical connections in a virtual star network.

Figure 3 is a schematic block diagram of a branch node in a virtual star network.

Figure 4 is a schematic block diagram of a central node in a virtual star network.

Figure 5 is a schematic block diagram of a communications network including two interconnected virtual star networks.

Figure 6 is a flow diagram of a process for transmitting messages in a virtual star network.

SUMMARY

In one aspect, the invention provides a method of transmitting a signal over a network. The network includes a central node and one or more branch nodes connected by a transmission medium. The transmission medium includes one or more signal channels. Each branch node includes an add/drop filter operable to receive signals on one or more signal channels transmitted over the network and add signals on the same channels for transmission to one or more other nodes in the network. The method includes receiving a signal on at least one signal channel at a first node, determining a receive power level of the signal, generating a transmit signal for transmission to a second node, adjusting a power level of the transmit signal to approximate the receive power level and transmitting the adjusted transmit signal on the at least one signal channel to the second node.

Aspects of the invention can include one or more of the following features. The step of receiving can include receiving the signal on plural signal channels and the step of transmitting can include transmitting the adjusted transmit signal on the plural signal channels. The step of adjusting the transmit signal can include attenuating the transmit signal. The step of determining a receive power level can include monitoring the receive power level of the signal and the step of attenuating the transmit signal can include automatically attenuating the transmit signal based on the monitored receive power level. The step of determining the receive power level can include determining if an amplifier is included in the network between the first node and the second node, and if one is detected, not adjusting the power level of the transmit signal.

In another aspect, the invention provides a transmission system including a transmission medium comprising a plurality of signal channels and a first node coupled to the transmission medium. The first node is configured to transmit and receive a signal via one or more of the plurality of signal channels of the transmission medium. The transmission system includes a second node configured to receive the signal via one or more of the plurality of signal channels, measure a receive power level of the received signal, generate a transmit signal to be transmitted to another node, and transmit the transmit signal on the one or more plurality of signal channels to another node at substantially a same power level as the measured receive power level for the received signal.

Aspects of the invention can include one or more of the following features. The transmission medium can be configured as a ring network. The second node can include at least one add/drop multiplexer. The second node can be configured to receive and transmit signals using the plurality of signal channels of the transmission medium. The second node can include a demultiplexer capable of retrieving the signal via the plurality of signal channels of the transmission medium, a power monitor for monitoring a receive power level of the signal, an attenuator for attenuating a power level of the transmit signal, an intelligent controller operable to monitor the receive power level as determined by the power monitor and control the attenuation of the attenuator, and a multiplexer coupled to the attenuator. The multiplexer is capable of

transmitting the transmit signal via the plurality of signal channels of the transmission medium on which the signal was received. The first node can be configured to transmit to, and receive from, a node external to the network.

In another aspect, the invention provides a branch node in a network. The network includes a central node and one or more branch nodes connected by a transmission medium. The transmission medium includes one or more signal channels. The branch node include a demultiplexer capable of retrieving a signal received at the branch node on the one or more signal channels of the transmission medium, a power monitor for monitoring a receive power level of the signal, a transmitter for generating a transmit signal responsive to the signal, an attenuator for attenuating a power level of the transmit signal, an intelligent controller operable to monitor the receive power level as determined by the power monitor and control the attenuation of the attenuator so that the transmit power level approximates the receive power level, and a multiplexer coupled to the attenuator where the multiplexer is operable to couple the transmit signal to the one or more signal channels of the transmission medium on which the signal was received.

Aspects of the invention can include one or more of the following advantages. A system is provided for minimizing the isolation level required in a conventional add/drop multiplexor used in a communications network without sacrificing network signal degradation. An intelligent controller is provided for determining an optimal power output level for signals added at an add/port of an add/drop multiplexor in a communications network.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

One or more implementations of the invention simulate a star network topology using a ring network configuration. Implementations described herein will make reference to an optical fiber transmission media. However, it should be apparent to those who are skilled in the art that the teachings herein can be adapted for use with other transmission media as well.

Referring now to FIG. 1, the virtual star network 100 comprises at least one central node 102 and at least one branch node 104. The branch nodes 104 and central

node 102 are interconnected by network 108. Network 108 is configured in a physical ring configuration using a transmission media (not shown). Each node of virtual star network 100 is configured to support WDM, ~~and as such, each branch node 104 is~~ connected by one or more signal channels 110 to each other node in virtual network 100. While the physical configuration of virtual network 100 is a ring topology, network 108 is shown with direct connections between central node 102 and each branch node 104 so as to clearly indicate that each branch node has full access to one or more respective signal channels.

Each of the branch nodes 104 are capable of generating optical signals using one or more wavelengths that are separated from one or more other wavelengths generated by other of the branch nodes 104. Therefore, the same transmission media (e.g., optical fiber) can be used by network 108 to simultaneously transmit signals between branch nodes 104 and central node 102 on separate signal channels. In one implementation, each of branch nodes 104 includes a fixed optical add/drop multiplexor capable of generating and receiving a fixed set of optical signals for transmission on the signal channels. Alternatively, a variable optical add/drop multiplexor can be used to transmit and receive optical signals in variable wavelengths. The use and operation of the add/drop multiplexors is described in greater detail below.

At central node 102, the signals that are received on signal channels 110 are demultiplexed into individual signals that may be analyzed by central node 102 to determine the destination of the signal. Alternatively, branch nodes 104 can perform the analysis and include a destination tag in the transmission (e.g. a packet) to identify the destination. If the destination is one of the branch nodes 104, central node 102 forwards the signal using one or more signal channels for the destination branch node.

Central node 102 can be configured to forward a transmission to an external destination such as other communications networks (e.g., an external LAN or the internet) using external link 118. Similarly, central node 102 can receive external signals via external link 118 that may be forwarded to branch nodes 104. Central node 102 forwards an external signal to the intended destination using one or more signal channels 110 associated with the destination branch node. Using a WDM configuration, each of the branch nodes 104 can communicate at different wavelengths and at the full bandwidth of the virtual star network 100. Like a traditional star topology, each of the branch nodes 104 in the virtual star topology communicates with the central node 102 using the total bandwidth virtual star network 100. Further, since each of the branch nodes 104 uses a

different wavelength, a signal can travel past uninvolved branch nodes (i.e.. those branch nodes 104 that are not the intended destination branch node) to an intended destination node.

As used herein, add power refers to the power level of the signal added at a given node at the node's designated wavelength(s). Drop power refers to the power level of a signal received (and subsequently dropped) at the node at a same wavelength. In traditional ring-based systems, the add power is a fixed value, that does not exceed the maximum ratio of add to drop power for a given node. However, in an asymmetric central node configuration as disclosed herein, all signals start at the central node and end up terminating there as well. This means once reaching an add/drop node, signals are only required to travel back to the central node.

Central node 102 is configured in an asymmetric configuration and provides an initial point for power equalization and regeneration of all wavelengths without limitations due to optical isolation or filters. Central node 102 launches equal power on all wavelengths. Each of the periphery nodes (branch nodes 104) receive one or more signals (having a designated wavelength(s)) and re-adds signals having the same wavelength(s) back to the other signals transmitted on the star topology network. If the add power equals to the drop power and all the wavelengths start with the same power, then central node 102 can maintain power equalization of all channels around the ring. The mechanisms for adding and dropping power at a respective branch node are described in greater detail below.

Figure 2 shows the physical configuration of the virtual star network 100. Central node 102 is coupled by media 106 of network 108 in a ring to branch nodes 104A-104D.

<u>Branch Node</u>

Referring now to Fig.3, each branch node 104 includes an intelligent controller 302, an add/drop multiplexor 304, power monitor 305, receiver 306, transmitter (signal generator) 308 and a variable attenuator 310

Intelligent controller 302 is used to optimize the transmitted power from a given add/drop node (branch node 104). A branch node 104 close to central node 102 can transmit at a higher power, since the distance to get back to central node 102 is large and the local receipt power is also large. A branch node 104 that is far along the ring (toward central node 102) can transmit at low power since it is close to central node 102. By programming a branch node's intelligent controller 302 to transmit the same power as the received power for a given wavelength, all the wavelengths can be maintained at equal

power levels as they traverse the ring. In addition, by programming a branch node's intelligent controller 302 to transmit the same power as the received power for a given wavelength, less isolation is required between the add and drop ports of an optical add/drop multiplexor used by a branch node. The use and operation of optical add/drop multiplexors is described in greater detail below.

Intelligent controller 302 includes controller 320, memory 322 and communications channel 324. Controller 320 receives a signal from power monitor 305 indicative of the receive power for the particular wavelength(s) associated with a respective branch node 104. In response thereto, controller 320 generates a control signal that is coupled to variable attenuator 310. The amount of attenuation provided by attenuator 310 is determined based on the receive power, the power output from transmitter 308, the network configuration and other considerations. Controller 320 can be a central processing unit executing instructions stored in a memory (such as memory 322) for monitoring receive power and adjusting the transmit power for signals added by a respective branch node 104. In an alternative implementation, controller 320 can be a microchip controller including software for determining optimum power levels for branch node 104 and for controlling the attenuation of signals passing through variable attenuator 310. Memory 322 can be used to store parameter information including factory settings for the maximum ratio of add/drop power. In one implementation, memory 322 is used to store optical parameters of add/drop multiplexor 304. Communications channel 324 can be used by controller 320 to communicate with other nodes in the network (ring). Controller 320 can query other nodes for network or power information in order to optimize the transmit power level for a given node.

In one implementation, intelligent controller 302 is coupled to each other branch node 104 and receives information regarding network configuration via communications channel 324. More specifically, each branch node 104 can be configured to report to the each other node whether or not amplifiers are used in the communications network. An amplifier may be used in the communications network where the distances between branch nodes are too great. If no amplifiers are detected in the communications network, then intelligent controller 302 can increase the transmit power from an associated branch node 104 since there would be no advantage to keeping quality in all the signal levels. Where a given branch node is aware of the system configuration, an intelligent decision can be made about the ideal transmit power from the branch node.

Add/drop multiplexor 304 includes an add/drop wavelength filter 334 having an add port 330 and drop port 332. Add/drop wavelength filter 334 is coupled in line with transmission media 106 and is used to extract a desired wavelength signal passing on transmission media 106 and subsequently add a signal of the same wavelength back to transmission media 106. Add/ drop wavelength filter 334 may be of the form of an optical filter model WD1515-AD1, produced by JDS Fitel Inc., Nepean, Ontario, Canada. Drop port 332 is coupled to receiver 306 and power monitor 305. Transmitter 308 is coupled through variable attenuator 310 to add port 330.

There are limitations on the power levels allowed between the add/drop signals. The isolation provided by an add/drop multiplexor between the add and drop ports 330 and 332, respectively, is traditionally not complete. Some in-band leakage may occur between add and drop ports 330 and 332. For example, "light" can leak in an optical system from add port 330 and may interfere with the the signal received at drop port 332. Since both the add/drop signals are the same wavelength, even a relatively small amount of crosstalk may cause a degradation of signal quality. This is due to an effect referred to as coherent crosstalk, where crosstalk between signals having the same wavelength is significantly worse than between signals of different wavelengths.

To achieve a reasonable bit error rate, an isolation of at least 25 db is required between the add and drop signals. However, if the two signals are unequal, that is at different power levels, the problem is much worse. If the transmit power is higher than the receive power, then higher isolation filters would be required. A higher transmit power allows for transmission over longer distances, but higher isolation filters are more complex to manufacture and cost more.

In a traditional ring-based system, signals originate and terminate at different positions on the ring. This means that at each point of the ring different power levels may be present for different wavelengths due to their separate points of origin. Different power levels makes it very difficult for the use of conventional amplifiers in the communications network.

Accordingly, the present invention includes an asymmetric configuration having a central node 102 that includes a normalizer that performs power equalization across all wavelengths. In addition, each branch node is configured to match the receive power with the transmit power so that the power across all wavelengths of the channel in the communications network is approximately equal at all points in the network. As such, add/drop multiplexor 304 can be a low isolation filter. In one implementation, add/drop

multiplexor 304 is an optical multiplexor, model WD1515-AD1 from JDS Fitel Inc., Nepean, Ontario, Canada.

~~Power monitor 305 is coupled to drop port 332 of add/drop filter 334 and~~ monitors the receive power (drop power) of the signal received by receiver 306. Power monitor 305 may be of the form of an optical power measurement device produced by Fujitsu Microelectronics.

Receiver 306 is tuned to receive signals having one or more predefined wavelengths. The signals can have been generated by other nodes in the communications network, or by other devices external to the communications network. Receiver 306 receives signals intended for a respective branch node and can pass the signals on to other system components (not shown) for further processing.

Transmitter 308 generates signals having a predefined wavelength to be added by add/drop multiplexor 304 to media 106 for transmission to another branch node 104, the central node 102 or another device external to the communications network. Transmitter 308 can be configured to transmit signals of a fixed wavelength and having a predefined power level. The output of transmitter 308 is coupled to variable attenuator 310.

Variable attenuator 310 receives signals from transmitter 308, attenuates the signals in accordance with instructions from controller 320 of the intelligent controller 302, and passes the attenuated signals to the add port of add/drop multiplexor 304. In one implementation, variable attenuator 310 is an electronically controllable variable optical attenuator (VOA) produced by OZ Optics, Inc.

Controller 320 monitors local receive power as well as the maximum ratio of transmit to receive power that can be introduced. As described above, parameters associated with the add/drop filter can be stored in memory 322, including the maximum transmit to receive power ratio and filter characteristics associated with the local node. Controller 320 can set the power levels on the transmit side (using variable attenuator 310) so that the largest ring circumference can be achieved. If an amplifier is later introduced into the communications system to increase the number of nodes on the ring or the length of the ring, controller 320 can reduce the add power to align the power level with the rest of signals passing on the ring.

Signal Transmission

The ring begins at central node 102 where all signal channels (all wavelengths) are transmitted at equal power. As the signals travel around the ring their power is attenuated due to losses in media 106 (optical fiber). Upon reaching a branch node 104,

one or more of the wavelengths are removed from the ring by a local add/drop multiplexor 304 and their signals are processed a local receiver 306 and intelligent controller 302. The optical power level of received signals are measured by the local power monitor 305. The branch node 102 can reintroduce a signal at the "drop" wavelength(s) back onto the ring with different information encoded upon them using local transmitter 308. If the added signal is too strong it may interfere with the received drop signal. Local controller 320 determines an optimal output power level for the transmitted signals produced by transmitter 308, and controls variable attenuator 310 to ensure that the receive power matches the transmit power at the local branch node 104.

External Networks

Referring again to Figure 2, branch nodes 104A-104D may act as a link between network 108 and another communication system such as a local area network, for example, via lines 112A-112D and 114A-114D. Where, for example, network 108 is a metro-ring that connects buildings within a given geographic area, branch nodes 104A-104D link LANs within these buildings to the metro-ring. Thus, a LAN in one building can be dynamically connected to a LAN in another building using the variable connection capabilities of network 108.

When information is received via line 112A for transmission via network 108 to another LAN, for example, branch node 104A generates an optical signal having a wavelength associated with branch node 104A and adds the signal via line 116A onto network 108. The signal generated by branch node 104A travels, via one of branch node 104A's signal channels, at the full bandwidth of network 108, past branch nodes 104B-104D to central node 102.

Central node 102 receives the signal, as well as those signals generated by branch nodes 104B-104D. The signal generated by branch node 104A is separated from the other signals and analyzed by central node 102 to determine its destination. Once central node 102 determines the destination, central node 102 forwards the signal to its destination using one or more of the destination node's signal channels. If, for example, central node 102 determines that the signal's destination is branch node 104C, central node102 generates a signal on a signal channel (i. e., at a given wavelength) assigned to branch node 104C. The signal is transmitted via network 108 at full bandwidth past branch nodes 104A-104B to branch node 104C. If central node 102 determines that the destination is external to

network 108, central node 102 uses uplink connection 118 to forward the information to its external destination.

~~Central Node Configuration~~

Central node 102 is capable of generating and receiving each of the wavelengths that may be generated/received by branch nodes 104A-104D, analyzing addresses contained in the information received from branch nodes 104A-104D and forwarding the information to its intended destination.

Figure 4 provides a block diagram of central node 102. In the example of Figure 4, it is assumed that four signal channels or wavelengths may be transmitted via network 108 (e. g., one wavelength for each of branch nodes 104A-104D). Central node 102 may be configured to accommodate more or less than four signal channels. For example, central node 102 may accommodate one signal channel for each branch node. As is discussed in more detail below, more than one signal channel may be assigned to a branch node.

Demultiplexer 404 of central node 102 separates the signal wavelengths received on signal channels of network 108 into individual signals. Demultiplexer 404 may be, for example, a JDS Fitel demultiplexer model WD15016-DI. Demultiplexer 404 forwards the individual signals 406A-406D to switch 412 via ports 408A-408D, respectively. In one or more implementations of the invention, the signals that are transmitted via network 108 represent a packet of information that contains address data.

Switch (or router) 412 is configured to analyze a packet received via one of ports 408A-408D to determine the destination of the information. Switch 412 is configured to analyze the header information, determine the destination of the packet and forward the information to an output port of switch 412. Switch 412 may be, for example, a encore switch from PMC-Sierra, Inc. located in Burnaby, British Columbia, Canada.

Where the information is intended for a destination on network 108, switch 412 outputs the signal to multiplexer 424 via ports 418A-418B. Each of ports 418A-418D is connected to a wavelength transmitter of multiplexer 424. The wavelength transmitter that receives a signal transmits a signal at the destination's wavelength via network 108 to its destination. Multiplexer 424 multiplexes the individual signals received from switch 412 at their respective wavelengths onto

network 108. Multiplexer 424 may be, for example, a multiplexer model WD15016-Ml available from JDS Fitel.

For example, if branch node 104A generates a packet specifying branch node 104C as its destination node, the packet is transmitted via one of branch node 104A's signal channels on network 108 to central node 102. The signal is received by demultiplexer 404 of central node 102. It is assumed for this example that ports 408A-408D and 418A-418D are associated with the signal channels of branch nodes 104A-104D of Figure 2, respectively. Demultiplexer 404 separates out the signal received from branch node 104A and sends the packet that is represented by the signal to switch 412 via port 408A.

Switch 412 examines the packet to determine that branch node 104C is the packet's destination. Switch 412 outputs the packet on port 416C that corresponds to branch node 104C. Multiplexer 424 generates a signal for transmission via network 108 that corresponds to a signal channel of branch node 104C. Like a star topology, the signals that are transmitted between branch node 104A and 104C use network 108's full bandwidth. Further, as with a star topology, the signals are passed through a central node (e. g., central node 102).

External Links

If a destination outside network 108 is specified in a packet's destination address, central node 412 forwards the packet to the external destination via external link 118.

External link 118 may connect network 108 to another communications system or a node that does not reside on network 108, for example. Figure 5 provides an example of external links accessible via a central node according to one or more implementations of the invention.

Central node 702A can provide a link to the World Wide Web (WWW), or Internet, for example. A branch node that is connected to central node 702A can communicate (e. g., upload or download) information with the Internet via link 706. For example, branch node 512 of network 500A can transmit and/or receive information from the Internet via central node 502A. Branch node 510 can be linked to central node 502A (via link 508) to communicate with a branch that is connected to central node 502B (e. g., branch node 514) as well as to the Internet. Central node 502A is connected to central node 502B via link 504. In this case, a branch node that

resides on network 500A can communicate with a branch node that resides on network 500B. For example, branch node 512 of network 500A can transmit a packet using one or more of its signal channels to central node 502A that determines that the packet is destined for branch node 514 of network 500B. Central node 502A forwards the packet to central node 502B via link 504. Central node 502B transmits the packet via one of branch node 514's signal channels to branch node 514.

Information Transmission

In the virtual star topology, transmission of information from one branch node on the network to another branch node is performed using the central node according to one or more implementations of the invention. The information that is to be transmitted is contained in a packet that further contains addressing information. Examples of protocols that may be used to generate packets are Asynchronous Transfer Mode (ATM) or Internet Protocol (IP). The header and addressing information is determined according to the specific protocol used. Further, a branch node may specify a destination address as a tag thereby eliminating the need for the central node to determine the destination. In this case, the addressing information is contained within the tag.

Figure 6 provides a process flow for transmitting a packet using the virtual star topology according to one or more implementations of the invention. Figure 6 assumes that the central node identifies the destination (i. e., the source node does not provide a destination tag).

When the central node (e. g., central node 102) is initiated, central node 102 is programmed or in some way learns which header addresses are associated with which branch nodes. For example, central node 102 can retrieve a lookup table that associates header addresses with their respective branch nodes. Similarly, each branch node 104 is aware of the other nodes on the network.

At step 602, a branch node (e. g., branch node 104A) transmits a packet using one or more of its signal channels. The power level of the signal transmitted by the branch node 104A is optimized by intelligent controller 302 and may be set to be equal to the receive power for signals received at the drop port of the local add/drop multiplexor 302. At step 604, central node 102 separates the branch node 104A's signal into an individual signal. It is possible for branch node 104A to be assigned more than one wavelength. In this case,

branch node 104A may send the packet using more than one signal channel. This increases the amount of bandwidth that is available to a branch node. If, for example, branch node 104a uses two signal channels to send the information, the amount of bandwidth that is available to branch node 104a is doubled.

At step 606, the central node analyzes the packet's addressing information. At step 608, a determination is made as to whether the destination is on the network. If not, processing continues at step 614 to forward the packet to its destination via the external link (e. g., external link 118). If the destination is on the network, central node 102 transmits the packet using one or more of the signal channels (or wavelengths) associated with the destination branch node. In either case, processing of a packet ends at step 612.

While the invention has been described in terms of one or more implementations, it is contemplated that alterations, modifications and permutations thereof will become apparent to those skilled in the art upon a reading of the specification and study of the drawings. Furthermore, certain terminology has been used for the purposes of descriptive clarity, and should not be construed to limit the invention.

WHAT IS CLAIMED:

1. A method of transmitting a signal over a network, the network including a central node and one or more branch nodes connected by a transmission medium, the transmission medium including one or more signal channels, each branch node including an add/drop filter operable to receive signals on one or more signal channels transmitted over the network and add signals on the same channels for transmission to one or more other nodes in the network, the method comprising:

receiving a signal on at least one signal channel at a first node;

determining a receive power level of the signal;

generating a transmit signal for transmission to a second node;

adjusting a power level of the transmit signal to approximate the receive power level; and

transmitting the adjusted transmit signal on the at least one signal channel to the second node.

2. The method of claim 1 wherein, the step of receiving includes receiving the signal on plural signal channels and the step of transmitting includes transmitting the adjusted transmit signal on the plural signal channels.

3. The method of claim 1 wherein, the step of adjusting the transmit signal includes attenuating the transmit signal.

4. The method of claim 3 wherein , the step of determining a receive power level includes monitoring the receive power level of the signal and the step of attenuating the transmit signal includes automatically attenuating the transmit signal based on the monitored receive power level.

5. The method of claim 1 wherein, the step of determining the receive power level includes determining if an amplifier is included in the network between the first node and the second node, and if one is detected, not adjusting the power level of the transmit signal.

6. A transmission system comprising:

a transmission medium comprising a plurality of signal channels;

a first node coupled to the transmission medium, the first node configured to transmit and receive a signal via one or more of the plurality of signal channels of the transmission medium; and

a second node configured to

receive the signal via one or more of the plurality of signal channels,

measure a receive power level of the received signal,

generate a transmit signal to be transmitted to another node, and

transmit the transmit signal on the one or more plurality of signal channels to another node at substantially a same power level as the measured receive power level for the received signal.

7. The transmission system of claim 6 wherein the transmission medium is configured as a ring network.

8. The transmission system of claim 6 wherein the second node includes at least one add/drop multiplexer.

9. The transmission system of claim 6 wherein the second node is configured to receive and transmit signals using the plurality of signal channels of the transmission medium.

10. The transmission system of claim 6 wherein the second node comprises:

a demultiplexer capable of retrieving the signal via the plurality of signal channels of the transmission medium;

a power monitor for monitoring a receive power level of the signal;

an attenuator for attenuating a power level of the transmit signal;

an intelligent controller operable to monitor the receive power level as determined by the power monitor and control the attenuation of the attenuator; and

a multiplexer coupled to the attentuator, the multiplexer capable of transmitting the transmit signal via the plurality of signal channels of the transmission medium on which the signal was received.

11. The transmission system of claim 6 wherein the first node is configured to transmit to, and receive from, a node external to the network.

12. A branch node in a network, the network including a central node and one or more branch nodes connected by a transmission medium, the

transmission medium including one or more signal channels, the branch node comprising:

a demultiplexer capable of retrieving a signal received at the branch node on the one or more signal channels of the transmission medium;

a power monitor for monitoring a receive power level of the signal;

a transmitter for generating a transmit signal responsive to the signal;

an attenuator for attenuating a power level of the transmit signal;

an intelligent controller operable to monitor the receive power level as determined by the power monitor and control the attenuation of the attenuator so that the transmit power level approximates the receive power level;

and

a multiplexer coupled to the attentuator, the multiplexer operable to couple the transmit signal to the one or more signal channels of the transmission medium on which the signal was received.

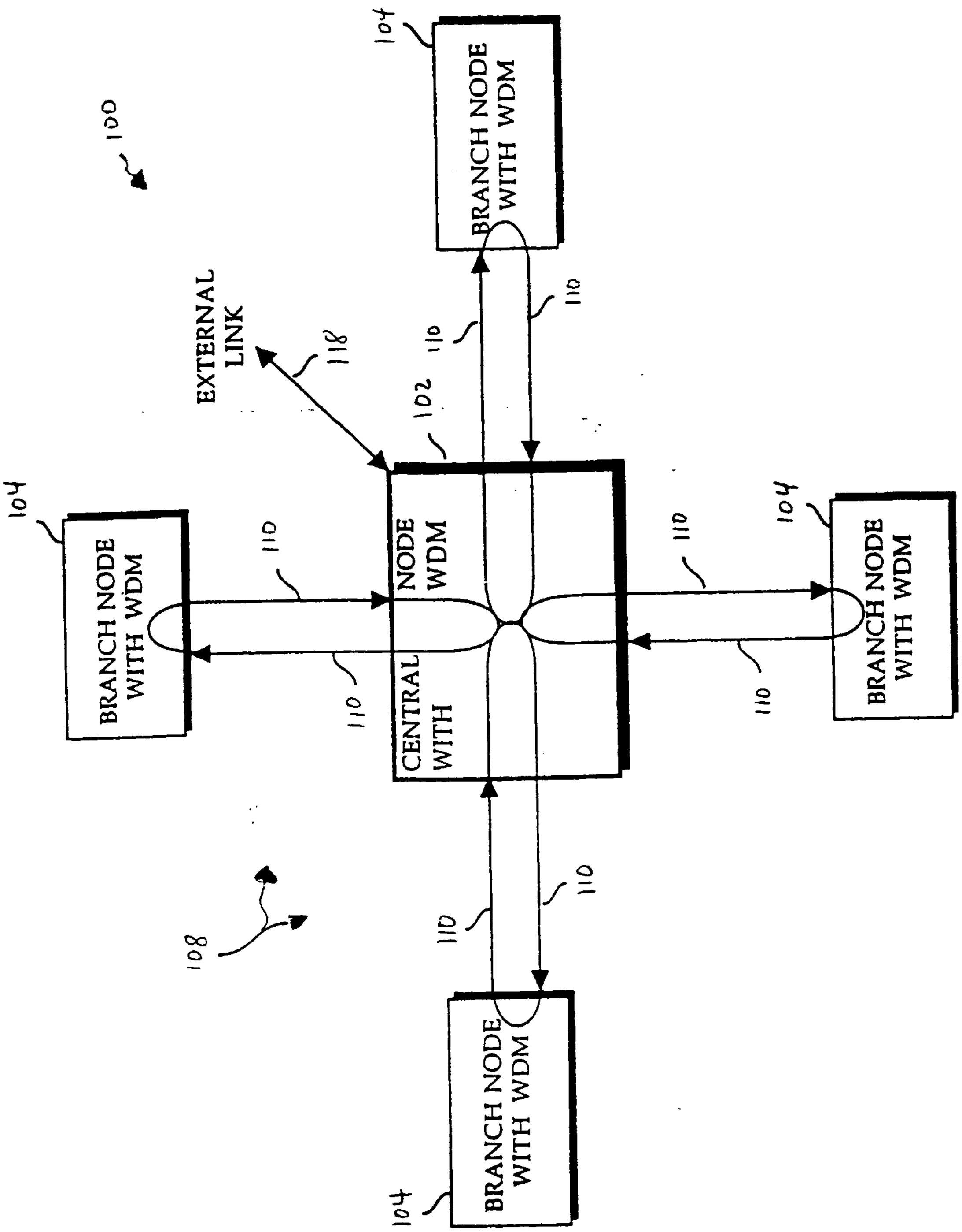
100
EXTERNAL LINK
118
102
CENTRAL NODE WITH WDM
BRANCH NODE WITH WDM
BRANCH NODE WITH WDM
BRANCH NODE WITH WDM
BRANCH NODE WITH WDM
104
104
104
104
110
110
110
110
110
110
110
110
108

Figure 1

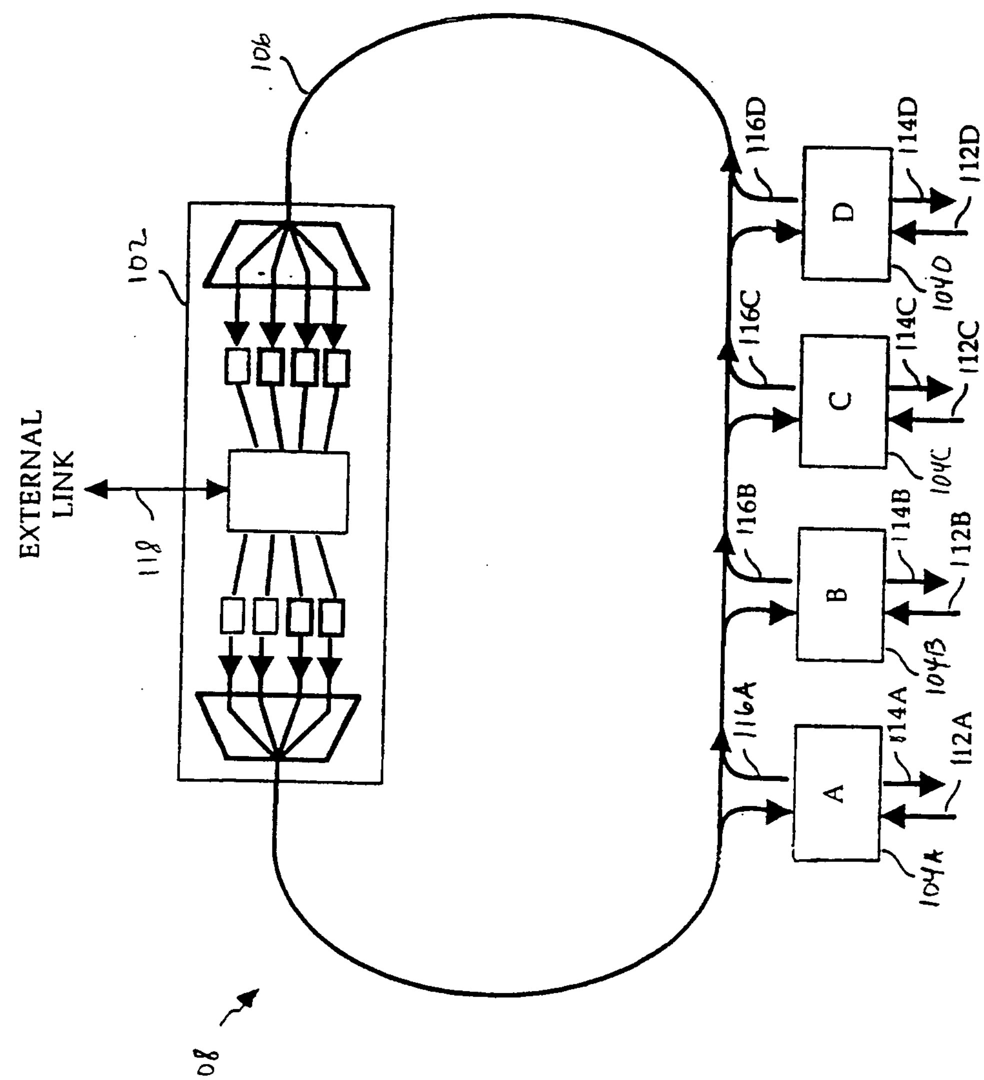
EXTERNAL
LINK
118
102
106
108
116A
116B
116C
116D
A
B
C
D
114A
114B
114C
114D
112A
112B
112C
112D
104A
104B
104C
104D

Figure 2

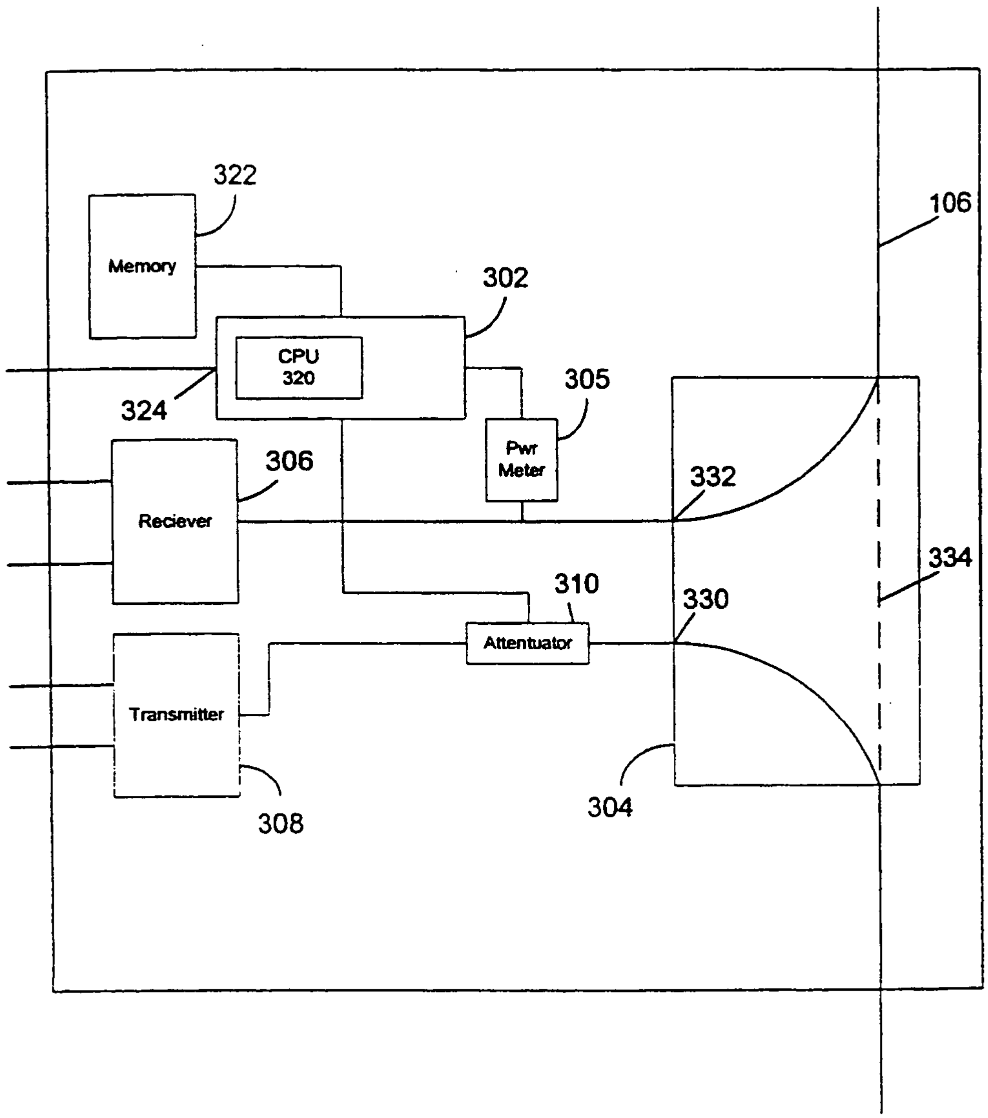
322
Memory
302
CPU
320
106
305
324
Pwr
Meter
306
Reciever
332
310
330
334
Attentuator
Transmitter
308
304

Figure 3

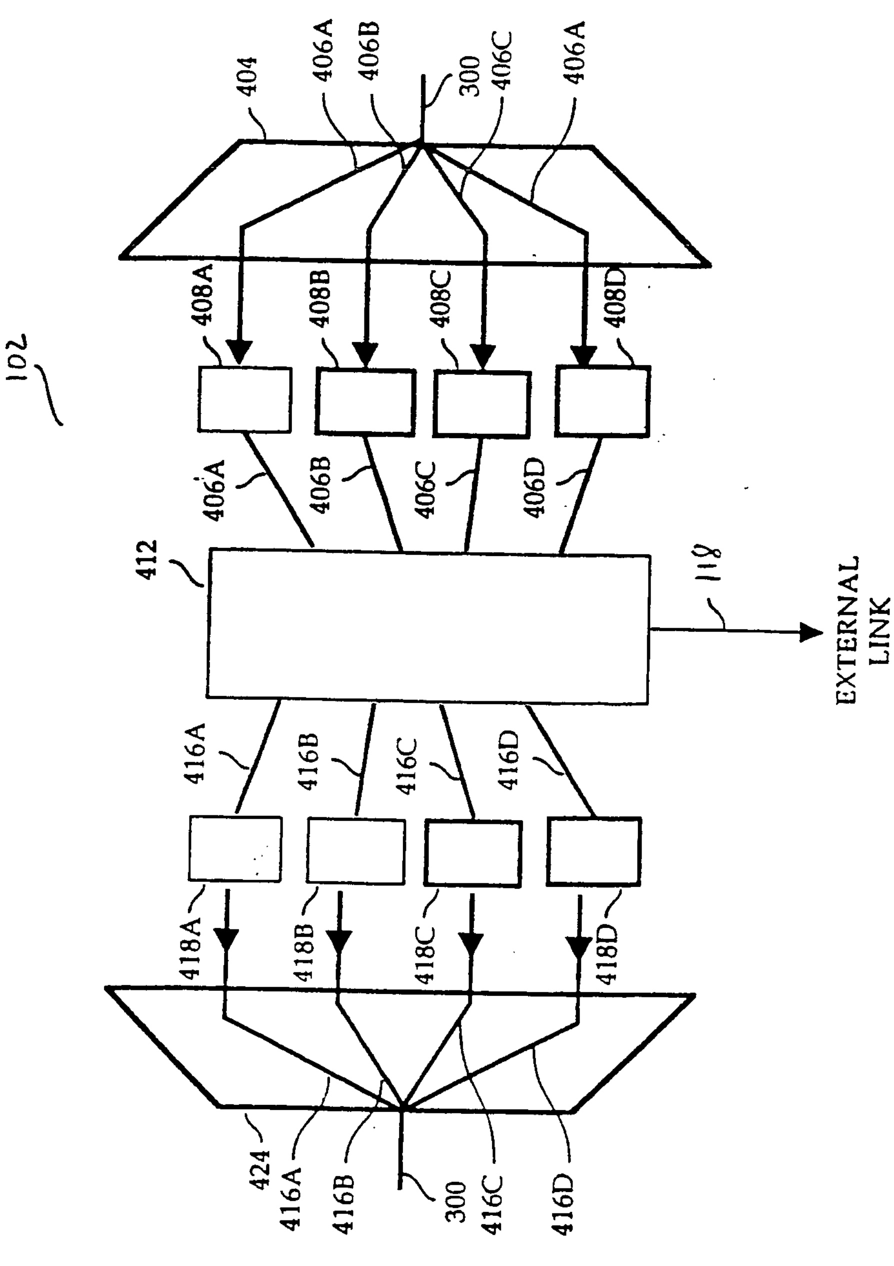
102
404
406A
406B
300
406C
406A
408A
408B
408C
408D
406A
406B
406C
406D
412
118
EXTERNAL LINK
416A
416B
416C
416D
418A
418B
418C
418D
424
416A
416B
300
416C
416D

Figure 4

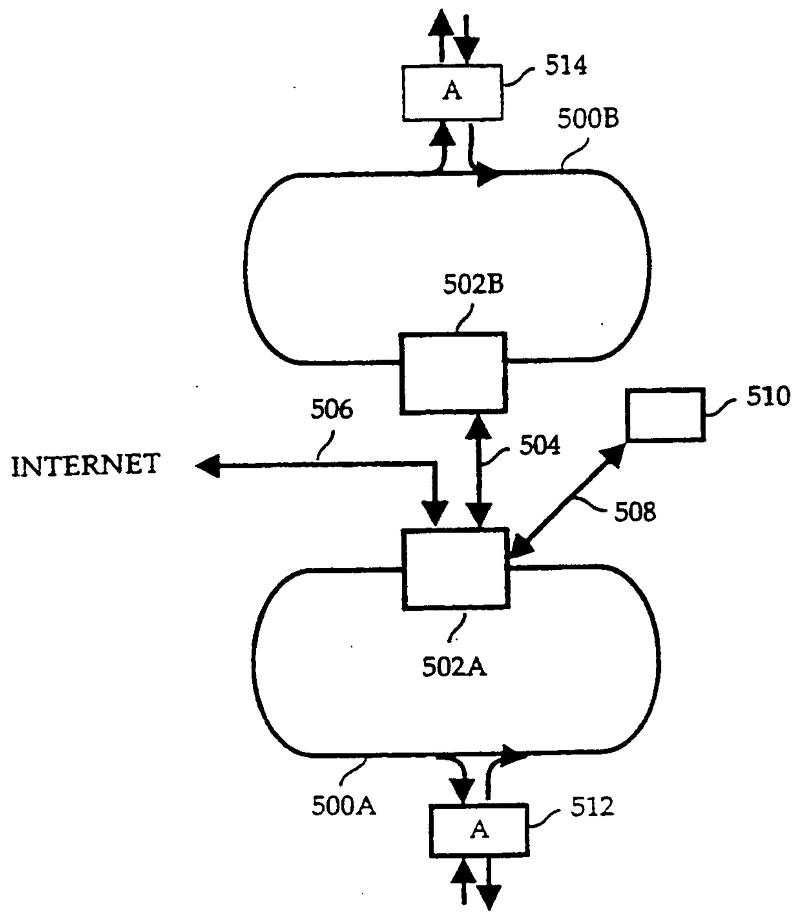

Figure 5

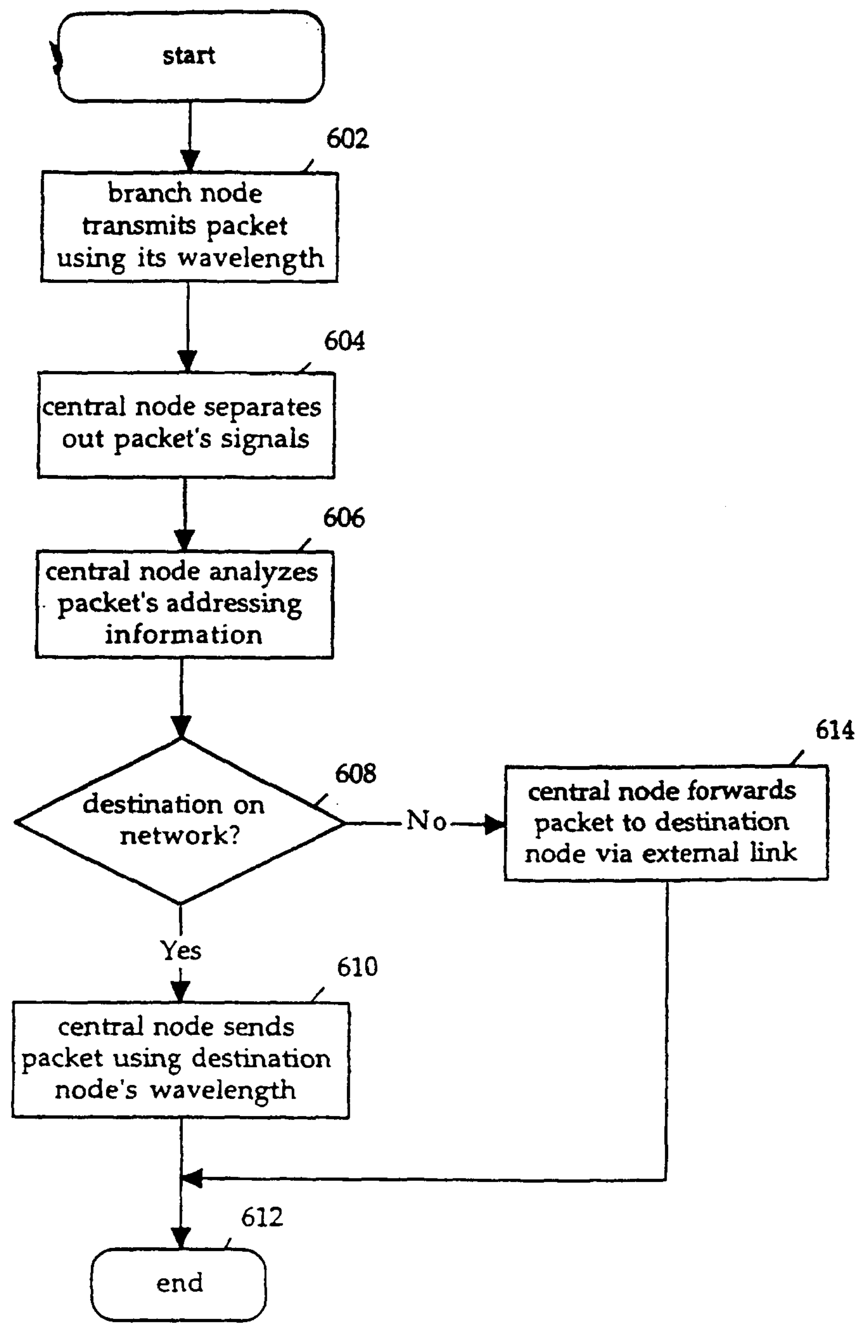
start
602
branch node transmits packet using its wavelength
604
central node separates out packet's signals
606
central node analyzes packet's addressing information
608
destination on network?
No
614
central node forwards packet to destination node via external link
Yes
610
central node sends packet using destination node's wavelength
612
end

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/32068

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04J 14/02; HO4B 10/20
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/535, 536, 537, 538, 540, 542, 544, 907, 916; 359/113, 114, 118, 120, 121, 124, 168

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,208,692 A (MCMAHON) 04 MAY 1993, FIG. 2, col. 6, line 60 to col. 8, line 27.	1-12
Y,P	US 6,115,157 A (BARNARD ET AL.) 05 SEPTEMBER 2000, FIG. 6, col. 8, line 56 to col. 9, line 55.	1-12
A	US 5,815,299 A (BAYAER ET AL.) 29 SEPTEMBER 1998, FIG. 2.	1 and 12
A	US 5,225,922 A (CHRAPLYVY ET. AL.), 06 JULY 1993, col. 3, line 26 to col. 6, line 29.	1 and 12
A,P	US 6,111,688 A (KOBAYASHI ET AL.) 29 AUGUST 2000, col. 3, line 27 to col. 10, line 49.	1, 12
A	US 5,812,710 A (SUGAYA) 22 SEPTEMBER 1998, FIG. 2.	1, 12

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 17 JANUARY 2001	Date of mailing of the international search report 26 FEB 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer DUONG, FRANK Eugenia Logan Telephone No. (703) 308-5428

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RAMAMURTHY ET AL. Optimizing Amplifier Placements in a Multiwavelength Optical LAN/MAN: The Equally Powered-Wavelengths Case, IEEE, September 1998, Vol. 16. No. 9. pages 1560-1569.	1, 12

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

370/535, 536, 537, 538, 540, 542, 544, 907, 916; 359/113, 114, 118, 120, 121, 124, 168